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# THE MARTIAN "CREST"

I. K. KOVAL'

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**THE MARTIAN "CREST"**

I. K. Koval'

Doctor of Physico-mathematical Sciences

Ivan Kirillovich Koval', who directs the lunar and planetary physics branch of the Main Astronomical Observatory of the Ukrainian SSR Academy of Sciences, is the president of the Commission on Planetary Physics of the Astronomical Council of the USSR Academy of Sciences. He is involved in investigation of the planets, especially of Mars. He is the author of more than 50 scientific papers in this field.

There is every reason to call 1971 the year of Mars: in the first place, in this year there occurred a great opposition of Mars, and astronomers did not let the planet out of the field of view of their telescopes for many long months. In the second place, this year was the year of the launch and triumphant completion of the flight to Mars of the Soviet Mars-2 and Mars-3 spacecraft, which initiated an upsurge in the direct study of the atmosphere and surface of the fabled Red Planet.

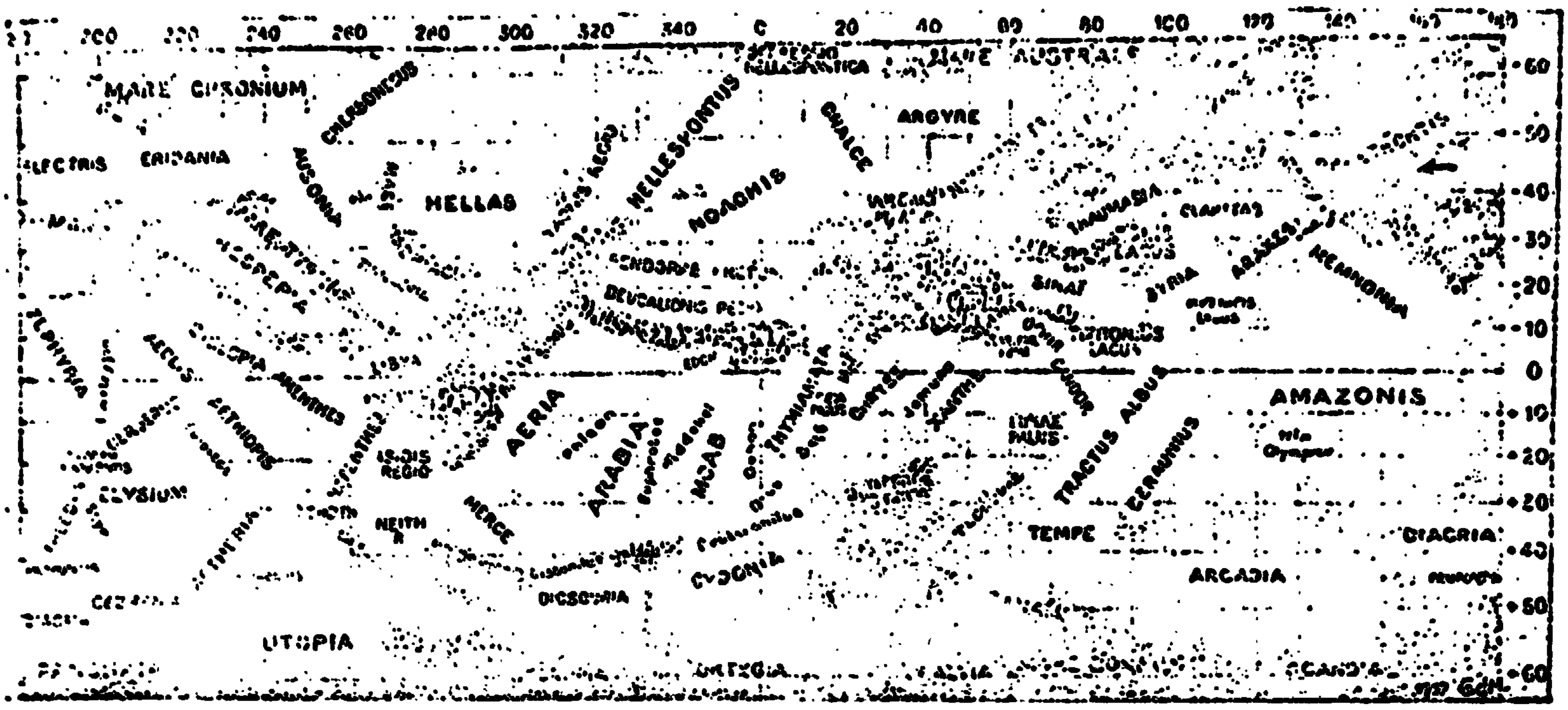
We already know quite a bit about Mars. The chemical composition of its atmosphere has been determined in its broad outlines; more or less reliable data have been obtained on the value of the atmospheric pressure and the transparency of the Martian atmosphere, and some data on the topography of individual regions of the surface have been derived. Crude estimates have been made of the density of the planet's surface layer, and so on. Both long-term varied ground-based observations and observations from the Mariner fly-by spacecraft have played a role in obtaining these data. However, the solution of the basic problems of aerophysics (from the Greek Αρεος, Ares, the god of war) is possibly only with the help of spacecraft operating for an extended time in areocentric orbits, and with the help of descent devices intended to measure the parameters of the Martian soil and to study the physical conditions prevalent on the planet. The successful accomplishment of a soft landing on Mars of the descent stage of the Soviet Mars-3 spacecraft initiated the phase of direct investigations of this planet, namely, the phase of rapid revision of hypotheses postulated over many decades and the confirmation of specific facts about the puzzling world of Mars.

Brief Information about Mars

Here we will list what is known reliably about Mars. The Martian year lasts 687 terrestrial days, and the Martian days are 37 minutes 23 seconds longer than the terrestrial days. The latter fact indicates that in one terrestrial day Mars lacks 9° of a complete revolution, and a terrestrial observer will only see a specific detail of the planet in the same location 40 terrestrial days later (9° x 40 = 360°). The inclination of the axis of rotation of Mars to the plane of its orbit is almost the same as for the Earth, namely, 66°.1. A change of the seasons is observed on Mars just as on the Earth, but the Martian seasons are almost twice as long as the terrestrial seasons. The planet's equatorial diameter is equal to approximately 6800 km. The average density of Mars is 3.9 $g/cm^3$, the acceleration due to gravity is 370 $cm/sec^2$, and the escape velocity is 5.2 km/sec.

An atmosphere on Mars was already detected at the start of the current century. For various reasons, the atmospheric pressure on Mars was determined earlier without much reliability. For three decades, we assumed that it was only ten times less than on the Earth, namely, about 100 millibars. To the chagrin of some, ten years ago it was necessary to lower this value categorically by more than an order of magnitude. This revision was due to the fact that earlier the pressure was determined from data on the atmosphere's transparency, and then it turned out that it is impossible to do this, since the atmosphere of Mars is strongly contaminated by aerosols such as dust particles, ice crystals, and carbon dioxide gas. Since the pressure is determined only by the purely molecular medium, the neglect of the aerosol component of the atmosphere resulted in exaggerated values of the pressure. Thereupon, spectroscopic methods which permitted excluding the effect of aerosols were used, and the average pressure on Mars turned out to be 6 millibars.

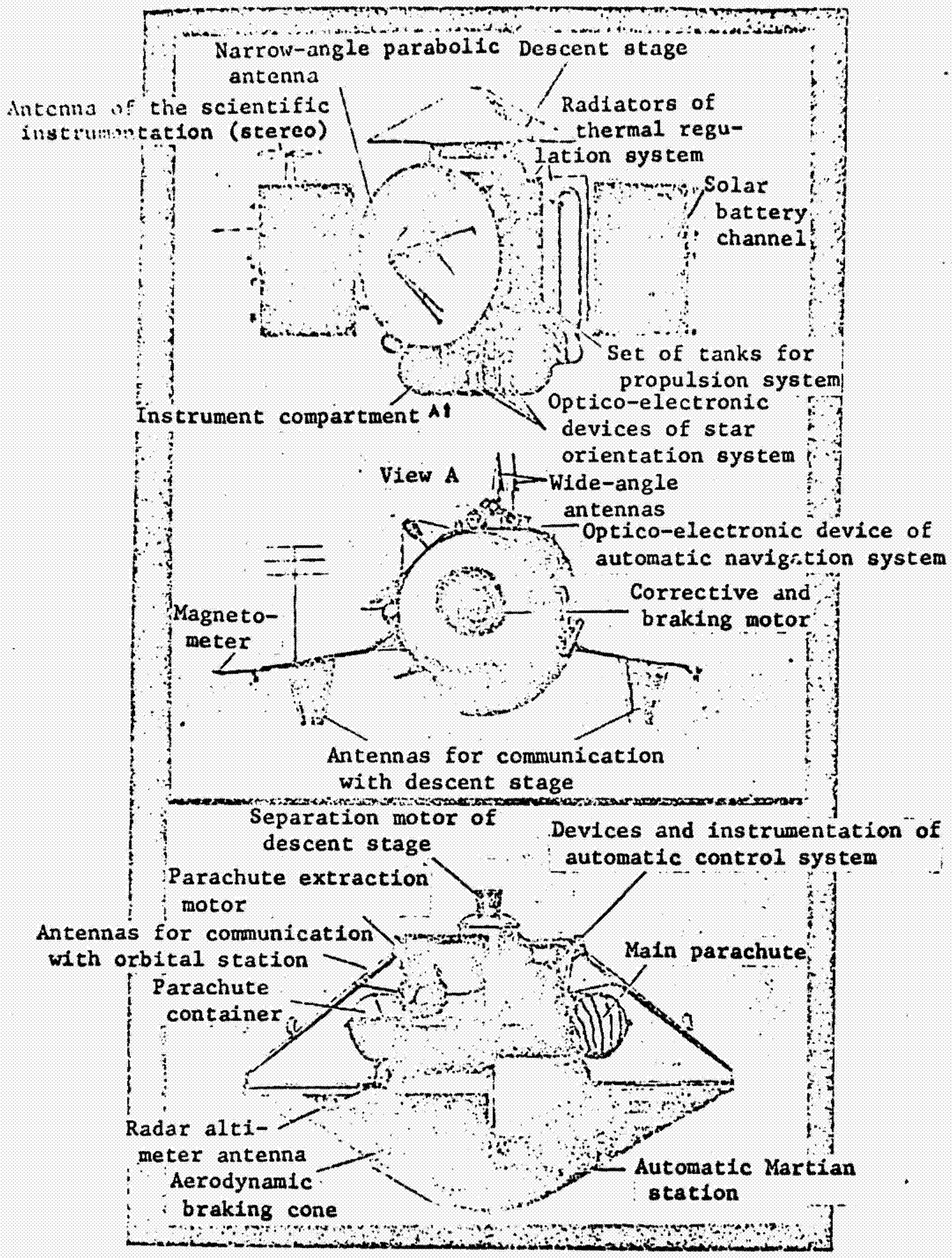
Radar and spectroscopic observations have shown that height differentials exceeding 10 km occur on the surface of Mars. Although these methods are essentially different, they both possess comparable capabilities in angular resolution and with respect to the value of the working zone on the planet's surface. Radar observations, which are based on the direct measurement of the distance from the instrument to the central portion of the planet's disk, give an angular relief profile with a resolution of several hundreds of




Map of the surface of Mars (from P.G. Kulikovskiy's book Amateur Astronomer's Handbook, Nauka Press, 1971). The site of the soft landing (45° S., 158° W.) of the Mars-3 spacecraft descent stage on December 2, 1971, is indicated by an arrow. (On this map south is up and west is to the right.)

kilometers for the central parallel of Mars. Contemporary radar equipment permits recording the instants of transmission and reception (reflected from the planet) pulses with an accuracy which corresponds to approximately a kilometer of altitude at the surface of Mars. The spectroscopic relief measurements are based on the determination of the amount of gas in the line of sight above different regions of the surface. It is evident that there is more gas in depressions than on protuberances.

Successful experiments with the help of the Mariner spacecraft significantly supplemented the arsenal of topographic data referred to comparatively small features of the surface. These data led to the discovery of a number of new exceedingly interesting peculiarities of the structure of the Martian surface. Thus, taking account of the macrorelief, the atmospheric pressure on Mars can vary from 1 to 10-12 millibars. Approximately 25% of the surface of Mars is covered by the dark spots of the Martian "maria." It has been well determined that their average contrast with the adjoining bright "continent" regions is 30-40%, and that they are rougher than the continents. The density of the material in the surface layer on the continents is estimated on the basis of radioastronomical observations to be 0.8-1.5 g/cm$^3$. There are indications that the density of the material in the surface layer in the maria is somewhat greater than in the continents.




Layout of the Mars-3 spacecraft (above) and the spacecraft descent stage (below).

The atmosphere of Mars consists mainly of carbon dioxide gas, and the amount of nitrogen, if it is present, does not exceed a few percent. The amount of water vapor in the atmosphere of Mars is very low, and is equivalent to a layer of precipitated water with a thickness of 5-10 microns. Oxygen and ozone have not been detected in the Martian atmosphere. The latter fact indicates that Mars is not protected from ultraviolet radiation in the 1700-300 Å spectral region (as is well known, mainly ozone serves as the barrier on Earth). The atmosphere of Mars is capable of significantly absorbing the ultraviolet radiation only in the 100-1700 Å region. This absorption is accomplished by carbon dioxide gas. There is an ultraviolet window on Mars in the ozone absorption region, and it appears that the window is wide open. It breathes death on whatever biological forms are on the planet. But life is tenacious and capable of putting up a strenuous struggle for its existence on Mars in the presence of the open ultraviolet window in the ozone absorption region. Thus, the data cited above still do not eliminate hope of encountering at least the most primitive life forms on Mars.

As for the climate of Mars, it is not really very severe. The two factors which basically determine it are the planet's distance from the sun and the density and composition of the Martian atmosphere. At Mars' average distance from the sun, the temperature of the equatorial regions at the Martian noon is close to 0°C. It is interesting that the temperature of the Martian atmosphere at its base is 20-30° lower than the temperature of the surface. There is almost no such difference on the earth. The evening or morning temperature of the surface of Mars is approximately 50° lower and the nighttime temperature (theoretical estimates) is lower by more than 100°, so that the diurnal temperature variations on Mars are far larger than on the Earth. This fact is explained both by the properties of the Martian atmosphere and by the thermal conductivity of the Martian soil, which is lower than the Earth's. Quite recently a successful measurement was carried out with the help of the Mariner spacecraft of the temperature of the polar region of Mars at the time when the polar cap was situated there. It was found that the temperature there is about -130°C. Carbon dioxide gas should freeze out at such a temperature under the conditions on Mars. From these data, the conclusion was drawn that the polar caps consist of carbon dioxide. But this conclusion is in need of additional confirmation.

All the enumerated data have been derived prior to the great opposition of Mars in 1971. What new facts will we find out about Mars during this period?

The Great Opposition

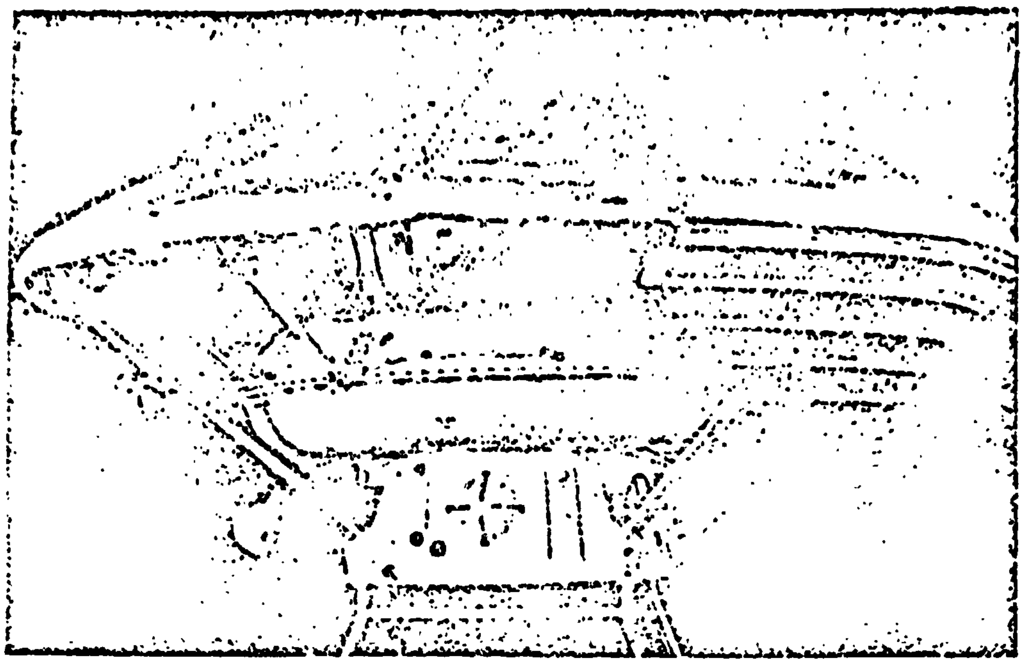
At the times of the great oppositions, which occur every 15-17 years, the distance between Mars and the Earth is decreased to approximately 66 million km. At the time of "ordinary" oppositions, which occur approximately every 26 months, the Earth-Mars distance is about 80 million kilometers, on the average. Thus, during the period of a great opposition, very favorable conditions exist for a wide variety of investigations of the planet over an extended time, including investigations for the study of various features on the disk of Mars. One of the distinctive features of great oppositions is that these periods correspond approximately to one and the same time of year on Mars, specifically, when spring is changing into summer in the planet's southern hemisphere.

In 1971, the minimum distance between Mars and the Earth occurred on August 12, but astronomers had undertaken their observations by June in order to secure as broad a period as possible of the spring-summer season in the southern Martian hemisphere. We recall that the day of the vernal equinox for the southern hemisphere of Mars was May 16, and the day of the summer solstice was October 9, 1971.

Noticeable changes usually occur on Mars just at the period of the great oppositions: an intensive melting of the southern polar cap is observed. Sometimes the shapes and brightnesses of individual regions of the Martian surface vary, and, finally, dust storms develop which result in a rapid decrease in the transparency of its atmosphere over enormous regions of the planet. The study of the data from many different observations of Mars during the great oppositions of 1924, 1939, and 1956, and also of the general meteorological situation on the planet during many ordinary oppositions, has made it possible to formulate the most important problems for observations of mars during the great opposition of 1971.

As early as 1970, the Commission on Planetary Physics of the Astronomical Council of the USSR Academy of Sciences discussed and confirmed a plan of observations of Mars in our country by ground-based methods for the period of the great opposition of Mars. Taking into account the fact that the height of Mars above the terrestrial horizon was comparatively small for the territory of the USSR during the 1971 opposition, observations were carried out primarily at the southern observatories of our country which are equipped with large instruments, specifically, at the Crimean Astrophysical Observatory of the USSR Academy of Sciences, the Shemakhinskaya Astrophysical Observatory of the Azerbaijan SSR Academy of Sciences, and at the Astrophysical Institute of the Tadzhik SSR Academy of Sciences. Some observations were also carried out at the Kharkov University Astronomical Observatory, at the Main Astronomical Observatory of the Ukrainian SSR Academy of Sciences in Kiev, and at other observatories.

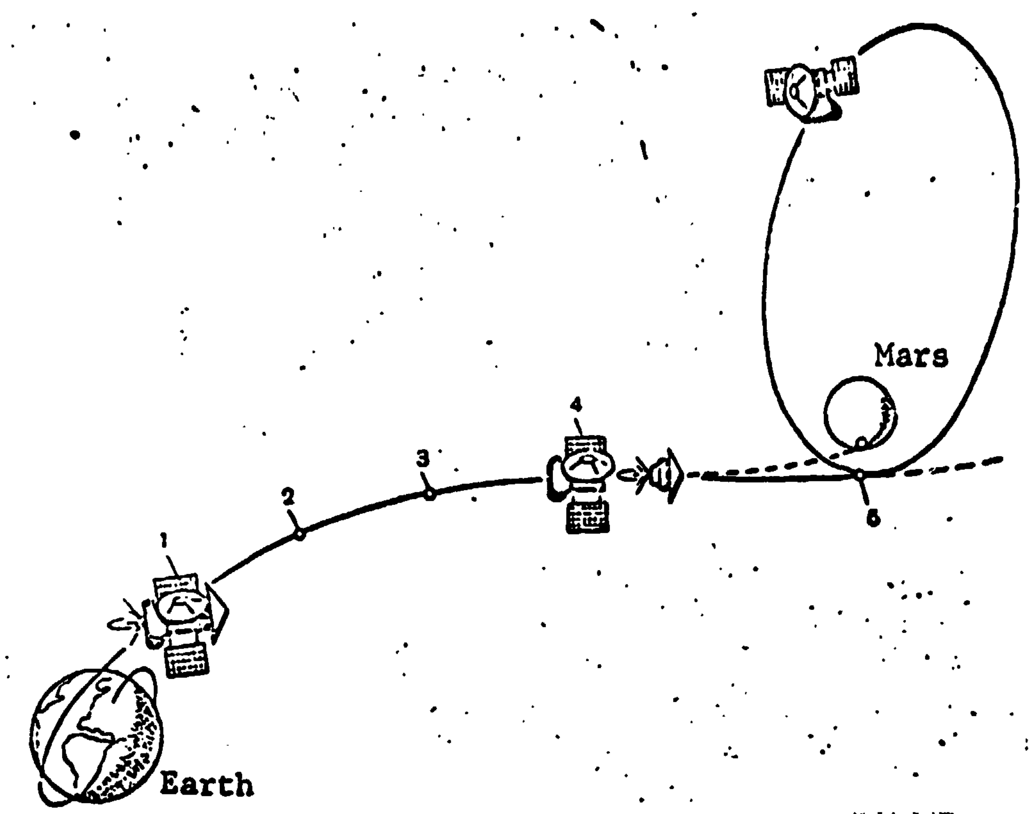
Tens of thousands of television photographs of Mars were obtained at the Crimean Astrophysical Observatory, which have led to detailed monitoring of the condition of the Martian atmosphere by recording and tracing the development of various kinds of cloud features and by making estimates of the transparency of the Martian atmosphere in various spectral regions. Together with astronomers of the Main Astronomical Observatory of the Ukrainian SSR Academy of Sciences, they also carried out important polarization observations of the disk of Mars which have yielded independent estimates of the properties and concentration of aerosols in the Martian atmosphere.



Descent state of the Mars-3 spacecraft.

The astronomers of the Kharkov Astronomical Observatory, together with their coworkers of the Astrophysical Institute of the Tadzhik SSR Academy of Sciences, completed a broad program of photometric observations, along with the astronomers of the Main Astronomical Observatory of the Ukrainian SSR Academy of Sciences and the scientists of the Shemakhinskaya Astrophysical Observatory of the Azerbaijan SSR Academy of Sciences, where observations were carried out on one of the largest telescopes in our country, the 2-meter reflector. The infrared spectrophotometric observations of Mars which V. I. Moroz carried out in the Crimea are of great interest. These observations consisted of measuring the intensity of the infrared molecular bands of carbon dioxide gas at various regions of the Martian surface. Since the atmosphere of Mars consists mainly of carbon dioxide gas, height differentials on the Martian surface can be determined under the conditions of the rarified Martian atmosphere from variations in the intensity of the $CO_2$ bands on the disk of Mars.

On the basis of the unanimous conclusion of the observers, the atmosphere in the visible spectral region had its usual rather high transparency up to the middle of September. In contrast, the dark regions of the Martian maria were examined, and the picture, familiar to the observer's eye, of a gradual worsening of the visibility of the maria was noted towards the shorter wavelengths. As is now well known, the atmospheric pressure at the surface of Mars is a little more than two orders of magnitude less than on the Earth (such a pressure occurs at an altitude of about 35 km in the terrestrial atmosphere). For such an atmospheric pressure, a purely gaseous atmosphere should be almost completely transparent to visible light, and in general we would not be able to record it by visual or photometric observations.

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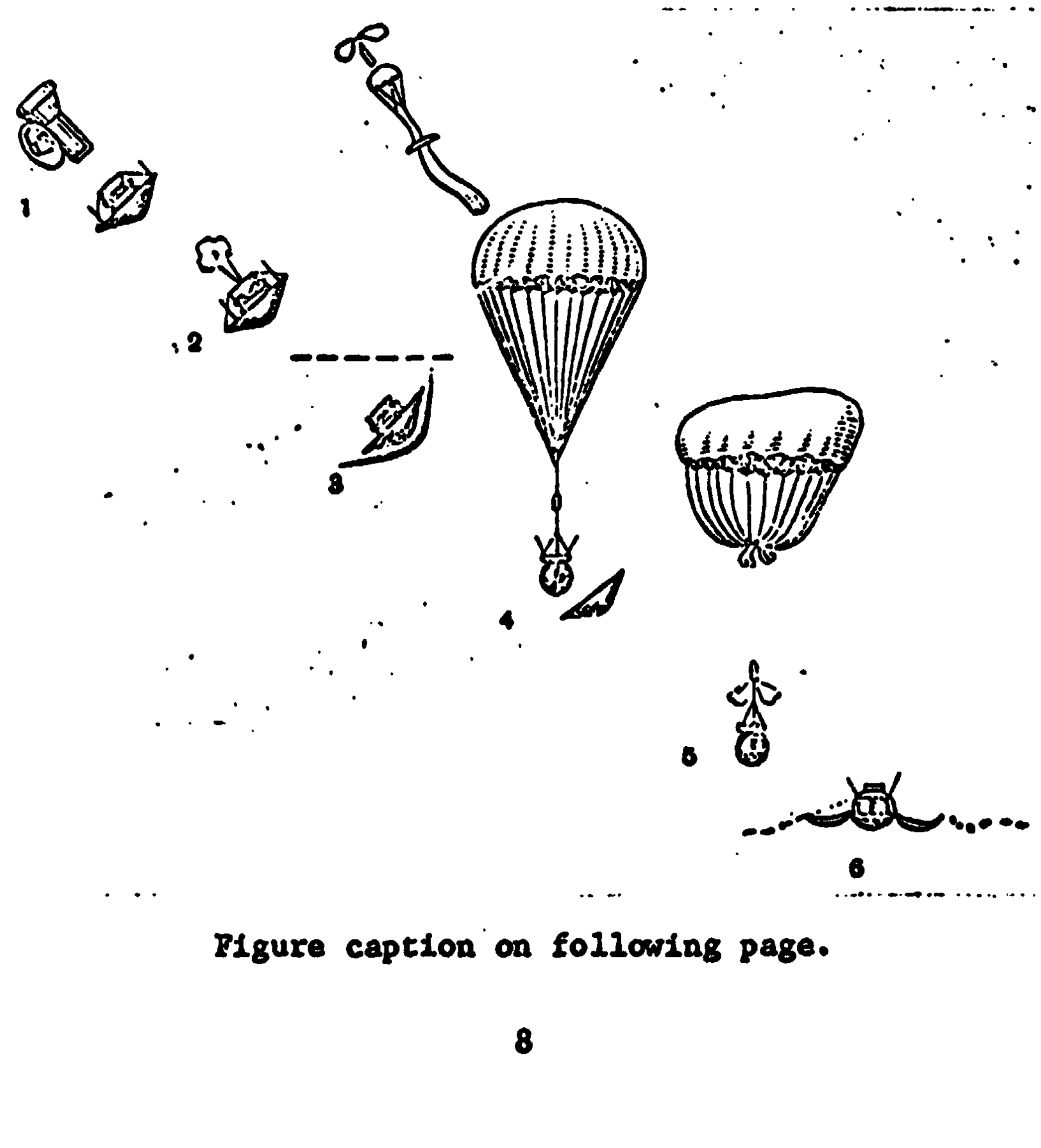


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Top: Layout of the interplanetary trajectory of the Mars-2 and Mars-3 spacecraft: 1, 2, 3 — trajectory corrections; 4 — separation of the descent stage from the orbital station; and 5 — deceleration of the station and transition to an orbit as a satellite of Mars.

Bottom: Layout of the landing of the Mars-3 descent stage: 1 — separation of the descent stage; 2 — firing of the descent stage motor; 3 — aerodynamic braking; 4 — parachute descent; 5 — firing of the soft landing motor and parachute deployment; and 6 — the descent stage on the surface of Mars in its operating position. The nominal boundary of the atmosphere of Mars is indicated by the dashed line.

Nevertheless, an atmospheric veil of variable density is almost always observed on Mars, and cloud features of various kinds are certainly recorded. These facts indicate that fine aerosols float in the rarified gaseous envelope of Mars and that these aerosols increase the optical density of the atmosphere. Variations in the density of the aerosol medium on Mars can be found by means of a comparison of the contrast of the maria during various observation periods. The greater the atmosphere's optical density is, the atmosphere itself evidently becomes brighter as a result of the scattering of light by the atmospheric particles. If light contrasts on the planet's surface are observed through such a scattering atmospheric veil, their true values will be more strongly blurred (smoothed, fogged) in the case of a measurement from outside as the atmospheric veil is more intense (denser). In the case of the usual transparency of the Martian atmosphere, maria on Mars observed in the red spectral region are almost twice as dark as the continents. During these periods, the transparency coefficient of the Martian atmosphere is close to 0.99 (for a cloudless atmosphere, the Earth's coefficient in this spectral region is $\approx 0.80$). In order that the Martian contrasts disappear completely, or more likely, decrease below detectable limits, the transparency coefficient of the planet's atmosphere has to decrease to approximately 0.1, as is the case during the periods of the violent dust storms.

A comparison of the contrasts made during June-August, 1971, did not show any noticeable change in the intensity of the equatorial band of Martian maria. This result indicates both the constancy of the Martian atmosphere's transparency in June-August of 1971, and the absence of a darkening of the maria of the southern hemisphere of Mars during the spring-summer period. The latter circumstance requires a new careful verification which can be carried out only after the final reduction of all the numerous long-term photometric observations. The question is, what did the former observations indicate about the seasonal variations of contrasts of the Martian maria. Hypotheses (including biological ones) exist with respect to the nature of this phenomenon, and probable agents are invoked on the surface or in the atmosphere of Mars which are capable of producing the darkening of the maria at the height of spring in the planet's southern hemisphere, i.e., during the period of the rapid decrease in the dimensions of the southern polar cap.

In the second half of September, the transparency of the atmosphere of Mars in the red spectral region strongly decreased, as is shown by the sharp worsening of the visibility of the Martian maria as well as by the significant decrease in the polarization of the light reflected by the planet in the direction of the observer. A detailed study of the observational data will provide more specific information on the origin and development of the violent dust storm on Mars, which for many weeks obscured from the observer's view the dark features of the Martian surface over almost the entire observable disk of the planet. However, by now it is possible to confirm that this phenomenon occurs only at comparatively rare periods corresponding to a specific time of year on the planet. It is sufficient to recall that at the end of August in 1956 (the year of the preceding great opposition of Mars), i.e., at approximately the same seasonal period, a similar but possibly less prolonged pattern was observed on Mars. Still earlier, during the period of the great opposition of 1924, the French astronomer Lyot also recorded significant dustiness of the Martian atmosphere by means of polarization measurements. During ordinary oppositions, i.e., at other seasonal periods on Mars, not enough reliable indications of any significant dust storms have been obtained.

The observations of 1971 will undoubtedly expand the possibilities of interpreting this exceedingly interesting phenomenon on Mars, which will be of great significance both for understanding the meteorology of Mars and for posing new problems in the investigation of the planet. A great deal of data indicate that the sharp increase in the aerosol content in the Martian atmosphere during dust storms is actually associated with the blowing off from the surface and the transport into the planet's atmosphere of a huge amount of fine particles (several microns in diameter) of mineral dust. The data concerning the optical density of the aerosol medium during the period of dust storms and concerning the duration of these storms should answer the questions about the force of the winds and the nature of the atmospheric circulation on Mars at this seasonal period, as well as certain properties of the planet's surface.

The appearance on Mars of the so-called violet clouds at the beginning of August 1971 was somewhat unexpected to astronomers. Such clouds usually appear at the morning and evening limbs of the planet's disk in the form of bright features. Already, on the basis of the fact that these clouds are most visible in the violet region (from which their name is derived) and gradually disappear towards the red spectral region, one can draw the conclusion that the clouds consist of very fine particles (less than a hundredth of a micron in diameter). On the basis of the chemical composition of the atmosphere of Mars and the most probable run of temperature and pressure with altitude in its atmosphere, one can assume that the violet clouds consist of carbon dioxide gas crystals. Aerosols of $CO_2$ are constantly present in the upper layers of the Martian atmosphere, but their concentration is increased in the coldest regions of the planetary disk. In this way, it is possible to explain the localization of the violet clouds primarily at the morning and evening limbs of the disk of Mars. During ordinary oppositions, the violet clouds are always easily visible on the disk of Mars, but on the other hand, during the great opposition their presence is a very rare phenomenon. For example, during the five-month period of the 1956 observations, these features were completely absent on Mars. During the most recent great opposition, the activity of the violet clouds on Mars was rather high. This new observational fact permits an extensive refinement of the physical conditions in the high layers of the Martian atmosphere at various times of the Martian year.

## More Details about the Dust Storm on Mars

What does this phenomenon on Mars represent, this dense atmospheric veil in which for several days the gigantic spaces of the dark Martian maria customary to the observer's eye are "submerged"? How much fine dust has been carried to an altitude of several kilometers and what is its course? How strong must the winds on Mars be in order to make its atmosphere so turbid on a global scale in such a small time interval?

The average distance of Mars from the Sun is about 227.8 million kilometers, but the elongation of the Martian orbit is approximately 6.5 times greater than that of the terrestrial orbit (the eccentricity of Mars' orbit is 0.093). For this reason, the difference between the maximum and minimum Mars-Sun distances amounts to more than 40 million kilometers. This fact indicates that the amount of solar energy incident on the planet at its minimum distance from the Sun is approximately 35% greater than at its maximum distance.

The great oppositions of Mars occur exactly at the periods of the planet's minimum distance from the Sun and correspond to the spring-summer season in the southern Martian hemisphere. It is precisely the southern hemisphere of Mars which is almost half covered by the dark features of the Martian maria, which reflect visible sunlight approximately two times worse than the surrounding continents. Thus during the great oppositions, the surface of Mars is heated up to a maximum extent in one hemisphere, which should lead to an anomolous strengthening of the air circulation on the planet.

In the absence of dust storms, the wind velocities on Mars evidently attain 40-50 m/sec. However, during the anomolous periods, taking into account the macrorelief of the surface, the wind velocity can significantly exceed 100 m/sec. The density of the Martian atmosphere at the surface is approximately 100 times less than the density of the Earth's atmosphere, and consequently the force of Martian storm winds is approximately an order of magnitude less than at the Earth's surface with a moderate wind. Nevertheless, if one takes into account the extreme dryness of the Martian climate and the approximately 2.5 times smaller gravitational acceleration compared to that at the Earth's surface, it becomes evident that the Martian winds at their maximum possible velocities are capable of blowing off from the surface and carrying to great altitudes and distances significant masses of fine dust.

Various estimates show that at the times of the dust storms, the transparency of the Martian atmosphere in the visible spectral region becomes several times less than the transparency of the Earth's cloudless atmosphere. Crude estimates indicate that during the periods of the dust storms there are several million tons of dust, with an average dust particle radius of several microns, in the atmosphere of Mars.

During the period of the dust storm observable on Mars at the time of the great opposition of 1956, it was established that the reflectivity of the dust cover at various wavelengths is the same as that of the bright continents of Mars in the absence of the dust storm. This fact indicates that the bright Martian continents, which occupy about 75% of the entire surface of the planet, are the source of the dust on Mars.

A striking distinctive feature of Mars is the fact that by the next encounter with the planet, i.e., by the next opposition of Mars after the opposition with a recorded dust storm, we again see with the usual contrast the dark Martian maria within their former boundaries. There is the puzzling process of the renewal of the Martian maria. Why isn't the dust able to fill them once and for all during the numerous dust storms? In this fact lies one of the puzzles of Mars, which has produced a number of tempting proposals concerning the possibility of the existence in the Martian maria of at least the lowest forms of vegetation or microorganisms.

Unfortunately, we do not know the extent to which the scale of the dust storm on Mars in 1971 is comparable with similar phenomena on the planet that have been observed during the past great oppositions of 1924, 1939, and 1956. At those times, no one succeeded (for various reasons) in recording the transparency of the Martian atmosphere for as long a period as in 1971-72 before and after the date of Mars' opposition, which is due to the investigation of the planet by spacecraft.

The unforeseen duration of the dust storm partially lowered the information content of the photographic and photometric observations of Mars from orbital spacecraft. Because of the dense dust cover for a long time it was impossible to obtain clear photographs of surface details. But on the other hand, the richest material concerning the properties and duration of a dust storm proved to be in our hands; it will assist both in the study of the physical conditions on the planet and in a more reliable prediction of the meteorological conditions of the Martian atmosphere.

The New Phase in the Investigation of Mars

Now each new great conquest of planetary astronomy is inextricably tied to the achievements of cosmonautics. In only a little more than 10 years, the science of the moon and the planets nearest the Earth has been approached, with the help of spacecraft and probes, completely factual knowledge about the nature of these objects of the solar system.

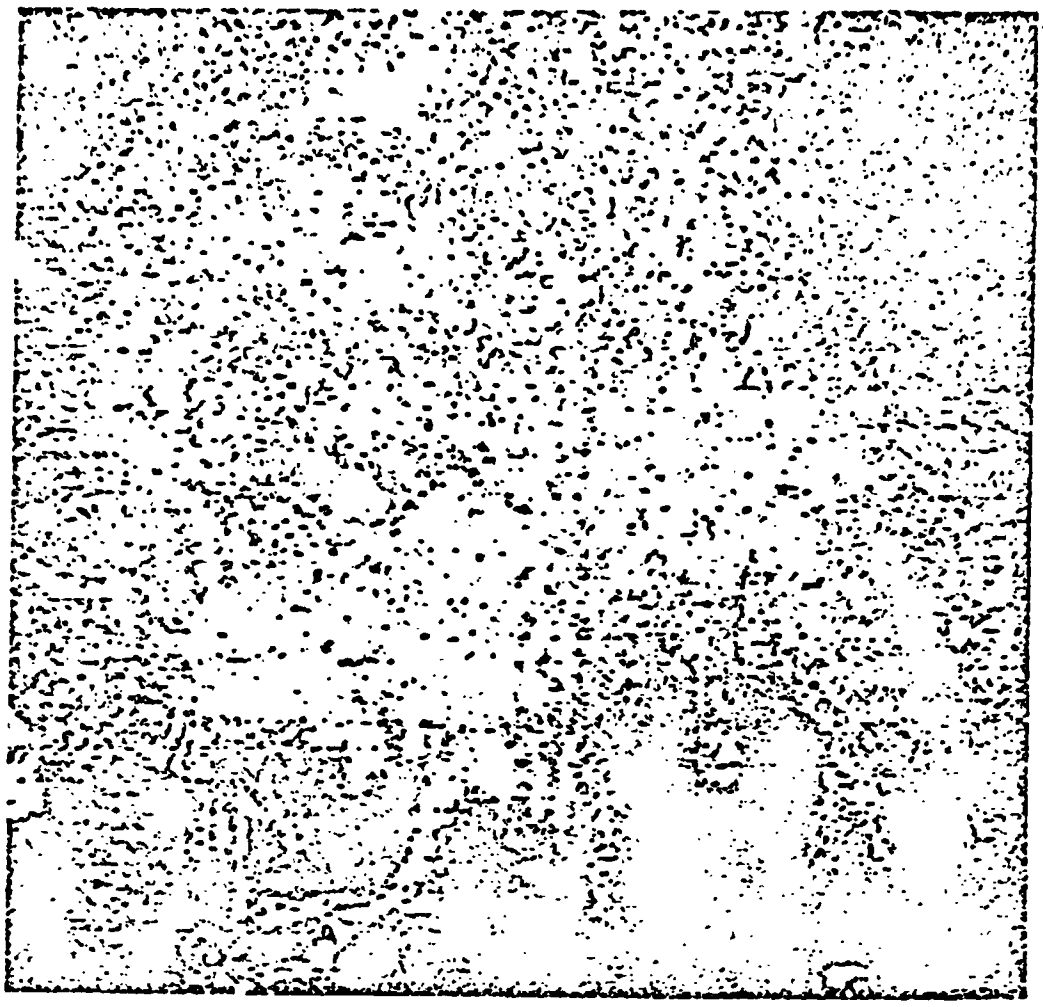
With the accomplishment of a soft landing on Mars of the descent stage of the Soviet Mars-3 spacecraft, an entire set of space experiments have been completed; they have opened up the way to subsequent more thorough direct measurements of the physical characteristics of the principally different planets. The atmosphereless moon; hot Venus enshrouded by a thick atmosphere, distant Mars with a liquid but erratic gaseous envelope — these are three worlds extremely dissimilar from one another which Soviet spacecraft have already reached.

The sequence of space experiments with respect to the Moon, Venus, and Mars reflects the growth of engineering difficulties which it was necessary to overcome in accomplishing a soft landing on the surfaces of the planets.

With respect to Mars, the problem of landing was solved by the successive application of aerodynamic, parachute, and reactive braking of the descent stage. Based on the conditions of a minimum weight of the descent stage, one physical peculiarity of Mars was utilized to its maximum in this instance, namely, the planet's rarefied atmospheric envelope.

The descent stage carried out its landing between the bright continental "islands" Phaetontis and Electris. One and one-half minutes after the landing, the automatic laboratory transmitted to onboard Mars-3 signals about its stay on the planet's surface. The Earth received the voice of its messenger located on Mars at a distance of about 140 million kilometers. The first Martian laboratory operated on Mars for less than one minute. On the whole we still know far too little about the specific small patch of the planet onto which the station descended and also about the meteorological conditions along the terminal segment of the station's descent track to be able to cite accurately the reason for the sudden termination of signals from the Martian surface.

The region of Electris, like other vast bright islands situated near the 50th southern parallel and similar to it, has received almost no investigation. It is only known that this is one of the reddest regions of the planet. For example, the Hellas region, which is situated on the same parallel, has almost the same color. It is now known that this region is a gigantic bowl (with a diameter of about 1600 km) about 4 km in depth, and completely devoid of craters, in contrast to the Hellespontus region adjoining it. The possibility is not excluded that Hellas is a basin covered with a thick dust layer. However, the photometric relationship of the bright islands does not give any reasons for analogy with respect to their other characteristics.



Mountainous region and foothills in the equatorial region of Mars which were least covered by the dust storm during the photography. In the evening with a low sun altitude, individual regions of the surface are covered by deep shadows.

Having accomplished the task of separating the descent stage, the Mars-3 spacecraft, like the Mars-2 spacecraft, proceeded to carry out a scientific program of investigation of Mars from the orbit of an artificial satellite. For about three months, abundant scientific information was returned to the Earth from on board the spacecraft, about the properties and composition of the Martian atmosphere, its structure, and the optical and physical characteristics of the planet's surface. Actually, the fact that the orbit of the Mars-3 spacecraft has a large eccentricity makes it possible to study the planet from various distances and significantly expands the range of problems being solved by both satellites. In particular, photographs of Mars taken from various distances (from tens of thousands to several thousand kilometers) and at various angles of illumination and viewing make it possible to carry out a number of interesting investigations concerning the macrorelief and also the optical properties of the surface and atmosphere of Mars.

The prolonged operation of the spacecraft has provided data from scientific investigations over a significant part of the Martian surface under various conditions of illumination and also under the conditions of the Martian night.

Scientists have only begun to process and analyze scientifically the information obtained, but it is already possible to talk about the most important discoveries, among which the most important is the establishment of the altitude dependence of the atomic hydrogen and oxygen content in the Martian atmosphere. Of exceedingly great significance are the data on the distribution of atmospheric water vapor over various regions of the surface, the structure of the thermal map over a considerable territory of Mars, the determination of the topographic characteristics, the investigation of the structure of the Martian surface, and so on.

The first automatic stations in the orbits of artificial satellites of Mars and the first soft landing of an automatic laboratory on the surface of the Red Planet are the first decisive steps of science on the path to a solution of the secrets of Mars.
UDC 523.43

Recent Information about Mars

During the period from January 22 to February 18, 1972, measurements were continued from onboard the Mars-2 and Mars-3 spacecraft of the temperature of Mars' surface and subsurface layers, its relief was investigated, and the characteristics of Mars' atmosphere and the space environment near the planet were determined.

The data obtained during this period show that the dust storm has concluded. The contrasts of surface details have increased in the red and near-infrared regions.

The measurements have shown that the temperature at a depth of several tens of centimeters from the surface is practically independent of the time of day. The pressure of the planet's surface lies within the range of 4-8 millibars in those regions where measurements have been carried out.

The boundaries of Mars' ionosphere have been determined. Its lower boundary lies at an altitude of 80-110 kilometers. The electron concentration increases sharply with altitude, and then decreases smoothly.

The measurements which have been carried out have led to the determination of the altitude dependence of atomic hydrogen and oxygen over the surface of Mars.